TECHNICAL NOTES FRL-TN-28

SYSTEMS ANALYSIS OF CLOVER CARTRIDGE

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by

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Approved:

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TABLE OF CONTENTS

OBJECT

To conduct a systems analysis of the Clover flash cartridge to determine the cause of premature detonations which occurred during series firing.

To investigate the behavior of three flash compositions, 30/20/50 calcium/aluminum/potassium perchlorate (FP 790), 60/40 potassium perchlorate/aluminum, and 60/40 calcium/potassium perchlorate in the Clover cartridge to determine whether premature detonations with the FP 790 system are attributable to the presence of calcium.

SUMMARY

A systems analysis of the Clover flash cartridge revealed that, of all components present, the lead azide and lead styphnate exhibit the lowest ignition temperatures (243° and 246°C, respectively) on furnace heating of test cartridges at 15°C per minute. FP 790 (30/20/50 calcium/aluminum/potassium perchlorate) ignited at 477°C, 60/40 potassium perchlorate/aluminum at 430°C, and 60/40 calcium/potassium perchlorate at 420°C. Skin temperature during the launching of a Clover cartridge assembly was found to be approximately 120°C, far below the ignition temperature of any of the cartridge components. Additional assemblies were preheated to temperatures of 120° and 140°C, and series fired. Cartridge skin temperatures of 200° and 270°C, respectively, were obtained. All cartridges fired in sequence with no malfunctions. It was thus established that none of the components of the Clover cartridge are prematurely ignited by heat generated during launching.

X-ray examination of Clover cartridge assemblies showed no discontinuities in component packing, and 40-foot free fall tests did not cause detonation of Clover cartridges containing FP 790 only.

A possible explanation of the premature detonations obtained during series firings is given based upon omission of the black powder/barium chromate/boron expelling charge.

INTRODUCTION

To date, pyrotechnic compositions containing elemental calcium as a fuel have produced the most efficient high altitude flash systems. Table 1 (p 7) compares the performance of two of the three systems investigated in this study, FP 790 (30/20/50 calcium/aluminum/potassium perchlorate) and 60/40 potassium perchlorate/aluminum.

During the testing of 7-unit Clover cartridge assemblies containing the FP 790 composition (Fig 1, p 11), several premature detonations occurred. No such prematures were experienced with the 60/40 potassium perchlorate/

aluminum composition. Consequently, a systems analysis of the Clover cartridge was initiated. Because the cartridges were loaded and initiated identically and differed only in terms of the use or non-use of calcium, the decision was made to examine these flash compositions under simulated operational conditions.

A diagram of an individual Clover cartridge is shown in Figure 2 (p 12). The central delay column contains a 90/10 barium chromate/boron composition. At the base of the column is a 175-mg charge of lead styphnate. The purpose of the styphnate is to ignite an expelling charge mixture of black powder and a 90/10 barium chromate/boron delay composition. Simultaneously with the cartridge expulsion, two side delay columns are ignited. These columns contain 90/10 barium chromate/boron delay composition. At the base of each column is a relay cup containing lead azide and lead styphnate. The flash composition is initiated by these relays at a distance of approximately 50 feet from the launching tube.

SYSTEMS ANALYSIS

Preliminary investigations were begun with the X-ray analysis of typical Clover cartridge assemblies (Fig 3, p 13).

Sensitivity data was compiled for the systems under investigation. Ignition temperatures, impact sensitivities, friction pendulum, and brisance tests were performed on all compositions.

Tests were devised to determine (1) what the ignition temperatures of the various components of the Clover cartridge are *in situ*, and (2) whether any component was igniting out of sequence and causing premature firing. Thirteen Clover cartridges were loaded, some to completion and others with specific components omitted. Thermocouples were affixed at positions in each cartridge corresponding to component location (Fig 4, p 14). Eleven cartridges were individually fired by heating in a furnace, and 3 cartridges were initiated by squib through the delay column. The furnace heating rate was adjusted to approximately 15°C per minute and the thermocouple temperatures were recorded on an 8-channel imprinting-type recorder or a Mosley Autograf X-Y recorder.

Clover cartridge skin temperatures were determined during series firing in order to determine the actual temperatures achieved during cartridge launching.

Four individual Clover cartridges, loaded with FP 790 composition in April 1959, were tested for luminosity characteristics at sea level and at a simulated altitude of 80,000 feet. These tests were conducted to determine whether any degradation of the calcium portion of the FP 790 composition had occurred during ambient storage for a period of over one year.

RESULTS

X-ray analysis of the Clover cartridge assemblies (Fig 3, p 13) showed all

delay columns to be intact, with no air voids apparent in the flash composition chamber. All cartridge components were present and properly positioned. The X-ray film showed the densities of the materials present to be homogeneous throughout, an indication that no settling or separation had taken place during handling and storage.

Sensitivity data was compiled for all materials under investigation (Table 2, p 8).

Two Clover cartridges containing only FP 790 composition were subjected to a 40-foot drop tower test. Each item was dropped 3 times without incident. It was therefore concluded that the flash composition confined in the Clover cartridge is not unduly sensitive to impact forces.

Ignition temperature data was obtained for the various systems by the methods described under "Systems Analysis." From Table 3 (p 9), it can be seen that lead azide and lead styphnate have the lowest ignition temperatures of the various components present. This is in line with the fact that the lead azide and lead styphnate exhibited the lowest 5-second ignition temperature values (Table 2, p 8) of any of the components present.

The delay column that was ignited by squib failed to generate a sufficiently high temperature to ignite the FP 790 flash composition in the surrounding compartment (Cartridge No. 5, Table 3).

Two Clover cartridges were completely loaded except that inert barium chromate was substituted for the black powder/barium chromate/boron expelling charge. The center delay column was initiated by squib and the cartridge detonated, indicating that the expelling charge was not necessarily functioning as a train in the normal sequence of operations (Cartridges 10 and 11, Table 3).

FP 790 composition, on furnace heating in a Clover cartridge, detonated at approximately 477°C (Table 3). The experimentally determined 5-second ignition value was 600°C (Table 2, p 8).

The 60/40 potassium perchlorate/aluminum composition was loaded into two Clover cartridges. These cartridges detonated at 430°C when furnace heated (Table 3). This composition did not give a 5-second ignition temperature value (Table 3, p 8).

Two additional Clover cartridges were loaded with a mixture of 60/40 calcium/potassium perchlorate. On furnace heating, they detonated at 420°C (Table 3). A 5-second ignition temperature of 470°C was obtained (Table 2) for the unconfined composition.

Table 4 (p 10) details the luminosity results obtained on testing 4 individual Clover cartridges (2 at sea level and 2 at a simulated altitude of 80,000 feet) which had been in ambient storage for over one year.

Eight Clover cartridge assemblies stored since April 1959 were fired 12 months later from a launching tube. The skin temperature of these cartridges, measured during series firing, was found to be approximately 120°C. This temperature level is far below that determined experimentally (approximately 477°C) as being necessary to detonate Clover cartridges containing FP 790 composition. Of some 63 Clover cartridges fired in these experiments, no misfires or prematures were observed. Two additional Clover assemblies were preheated to temperatures of 120° and 140°C and series fired. Skin temperatures of 200°C and 270°C, respectively, were obtained. All cartridges fired in sequence with no malfunctions. It was thus established that heat generated during standard functioning of Clover cartridge assemblies containing FP 790 composition would not trigger a premature detonation.

DISCUSSION OF RESULTS

Since calcium-containing compositions have always been involved when premature detonations occurred in the Clover cartridge system, and since there have been no mishaps with aluminum/potassium perchlorate compositions, indications were that the calcium was at fault.

Experimental findings, utilizing the Clover cartridge as test vehicle, showed the ignition temperature of lead styphnate and lead azide to be approximately 246° and 243°C. If either of these components were the cause of malfunction at these temperatures, then premature detonations would have occurred regardless of flash composition.

Both expelling charge (black powder and barium chromate/boron) and delay columns (90/10 barium chromate/boron) were common to all flash composition systems, and it thus seems unlikely that they would be responsible for misfires.

Typical luminosity results to be expected from testing the FP 790 composition at sea level and at a simulated altitude of 80,000 feet are shown in Table 1 (p 7). Increases of 150-200% in integral light, 300% in peak light, and 50% in time to peak light are normally encountered in going from sea level to high altitude. The luminosity results obtained in tests of four individual Clover cartridges under these conditions (Table 4, p 10) do not follow the above trends. They show increases of 30% in integral light and 25% in peak light, and a 50% decrease in time to peak light. This indicates that the calcium content of the FP 790 composition had degraded during ambient storage of the Clover cartridge assemblies, which had been in such storage for more than one year.

Because calcium is the sole additive to the system which prematured (FP 790), it was considered in detail. An examination of detonation temperatures obtained under confined conditions in the Clover cartridge revealed that FP 790, 60/40 potassium perchlorate/

aluminum, and 60/40 calcium/potassium perchlorate all detonated in approximately the same temperature range (477°C, 430°C, and 420°C, respectively). It is apparent that the presence of calcium did not appreciably increase the temperature sensitivity of confined flash systems. In addition, the skin temperature of Clover cartridges during normal launching was found to be approximately 120°C, far below that necessary to detonate any of the above flash systems. When cartridge skin temperatures of 200°C and 270°C were obtained on heating the Clover launching tube, no mishaps occurred on launching.

CONCLUSIONS

Flash compositions containing either calcium as the sole fuel or calcium in combination with aluminum are no more sensitive to slow heating in the Clover cartridge than are compositions containing aluminum as the sole fuel.

FP 790 or 60/40 calcium/potassium perchlorate compositions will not detonate on slow heating in the Clover cartridge until temperatures of approximately 477° and 420°C, respectively, are attained.

Cartridge skin temperatures obtained in launching of a Clover assembly are about 120°C, far below the ignition temperature of any of the cartridge components. Thus, none of the components in the Clover cartridge were prematurely ignited by heat generated during launching.

A possible explanation of the premature detonations obtained during series firing of Clover cartridge assemblies was apparent on firing two cartridges which were completely loaded except that inert barium chromate had been substituted for the usual black powder/barium chromate/boron expelling charge. Following squib initiation of the center delay columns, the cartridges detonated, indicating that the lead styphnate charge at the base of the center delay column had ignited the two side delay columns. It was therefore established that the cartridge would function without the presence of an expelling charge. Thus, if an expelling charge had been omitted from one cartridge in a Clover cartridge assembly, this cartridge would not have been expelled, and would have detonated in the launching tube.

EXPERIMENTAL PROCEDURES

Materials Used

Calcium, Valley Metallurgical Company, 36 microns

Aluminum, Allied Chemical Company, 15 microns, Specification MIL-P-14067

Potassium perchlorate, Western Co., 22 microns, Specification PA-PD-254

Barium chromate, J. T. Baker & Co., 1 micron, JAN-B-550

Boron, American Potash Co., 1 micron

Blending

The dry ingredients were weighed on a triple-beam balance and transferred to

a conductive-rubber container which was then sealed. Calcium was blended when the relative humidity of the environment was below 50%. Blending was performed on an Abbe ball mill for 45 minutes in accordance with P.A.C.U. Sequence of Operations No. 5.

Loading

The blended compositions were loaded into Clover photoflash cartridge series type (U) in accordance with the Sequence of Operations T1034-5-37 except that the photoflash powder was varied and in some instances other components were either omitted or added.

Testing

Tests were conducted in accordance with the procedures described under "Systems Analysis."

ACKNOWLEDGEMENT

The authors wish to acknowledge the valuable contributions and recommendations of Mr. Clement Campbell and Mr. Garry Weingarten.

TABLE 1

Luminosity characteristics of FP 790 and 60/40 potassium perchlorate/aluminum in the Poppy cartridge*

	At Sea Level		At 80,000 Feet (Simulated)	
	FP 790**	60/40 Mixture	FP 790	60/40 Mixture
Time to peak, msec	0.8	0.6	1.2	0.5
Peak × 10^6 candles	10.0	18.8	40.5	21.9
Integral light, × 10^6 candles				
$\frac{1}{10}$ max	52.0	48.1	129.0	33.7
Total	55.0	50.8	145.0	44.1
Duration, msec				
$\frac{1}{10}$ max	7.0	5.8	9.9	5.7
Total	14.0	11.1	20.5	18.8
Efficiency × 10^3 candlesec/gram***				
$\frac{1}{10}$ max	4.9	4.0	12.3	2.8
Total	5.2	4.2	13.8	3.6

*This table is included for purposes of comparison only. No luminosity studies have been conducted with the Clover cartridge except for storage data detailed in Table 4 (p 10).

**30/20/50 calcium/aluminum/potassium perchlorate.

***Total composition was 10.5 grams in all cases.

TABLE 2

Sensitivity data of Clover cartridge contents

Composition	Friction Pendulum Test		Impact Sensitivity, inches (P.A.)	Ignition Temperature, 5-Second Value, °C*	Brisance, grams of sand crushed
	Fiber Shoe	Steel Shoe			
FP 790 (30/20/50 Calcium/aluminum potassium perchlorate)	No action	Detonates	14.0	600	1.8
60/40 Potassium perchlorate/ aluminum	No action	Detonates	25.0	No ignition at 700°C after 120 seconds	6.3
Lead azide	Detonates	Detonates	3.0	340**	19.0
Lead styphnate	Detonates	Detonates	3.0	282**	24.0
90/10 Barium chromate/boron	Burns	Burns	12	600	Low value
Black powder	No action	Snaps	16	427**	8.0
40/60 Calcium/potassium perchlorate	No action	Complete detonation	16	470	0.4

*All compositions in unconfined state.

**Picatinny Arsenal Technical Report No. 1740, April 1958.

TABLE 3

Compartmental temperatures, °C, of the "Clover" cartridge at time of ignition (heating rate of furnace: 15°C/minute)

Temperature of:	Cartridge No. 1	2	3	4	5*	6	7	8	9	10*	11*	12	13
Delay column	260	296	243	477	457	466				NR**	NR		
Azide column	260	280	243							NR	NR		
Flash composition chamber													
Calcium/aluminum/potassium perchlorate	260	266	243	477	DNI***	471	482			430	430		
Aluminum/potassium perchlorate								430	430				
Calcium/potassium perchlorate												420	420
Styphnate column	266	266	246			Ignited at 205				NR	NR		
Expelling charge	274	280	257							Barium chromate	Barium chromate		
										NR	NR		
Furnace	302	299	302	554		Thermocouple broke	530						

*Column ignited by squib.

**Not recorded (Item completely loaded).

***Did not ignite.

TABLE 4

Luminosity characteristics of four Clover cartridges containing FP 790 in ambient storage for over one year

	Time to Peak, msec	Peak, $\times 10^6$ candles	Integral-Light, $\times 10^3$ candleseconds		Duration, msec	
			$\frac{1}{10}$ max	Total	$\frac{1}{10}$ max	Total
Sea level	1.0	34.0	148	158	10.0	19.0
Sea level	1.0	33.0	144	157	10.5	22.0
80,000 ft*	0.5	45.1	184	214	12.0	29.0
80,000 ft*	0.5	42.0	215	242	15.5	31.0

*Simulated.

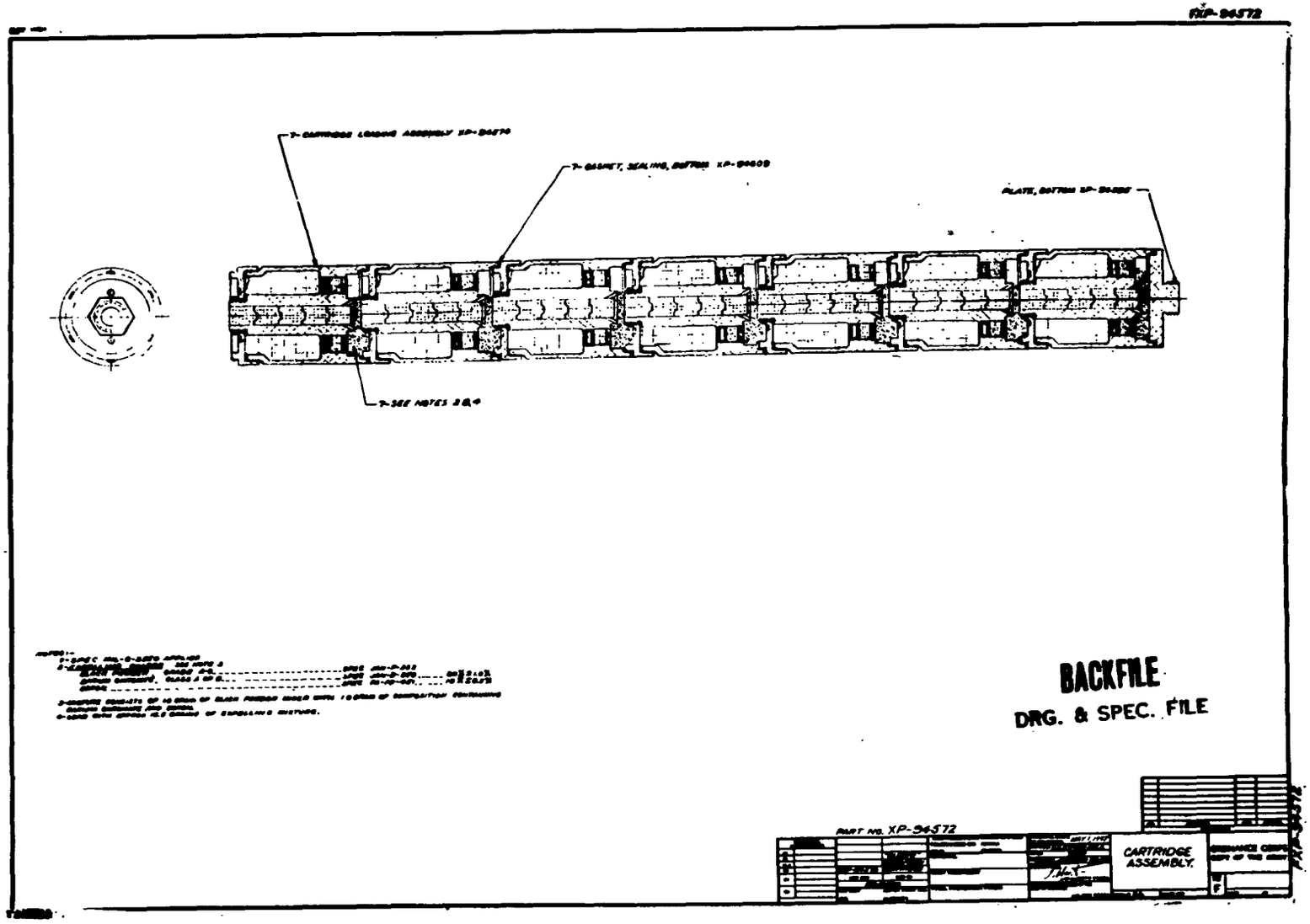

Fig 1 Seven-unit cartridge assembly

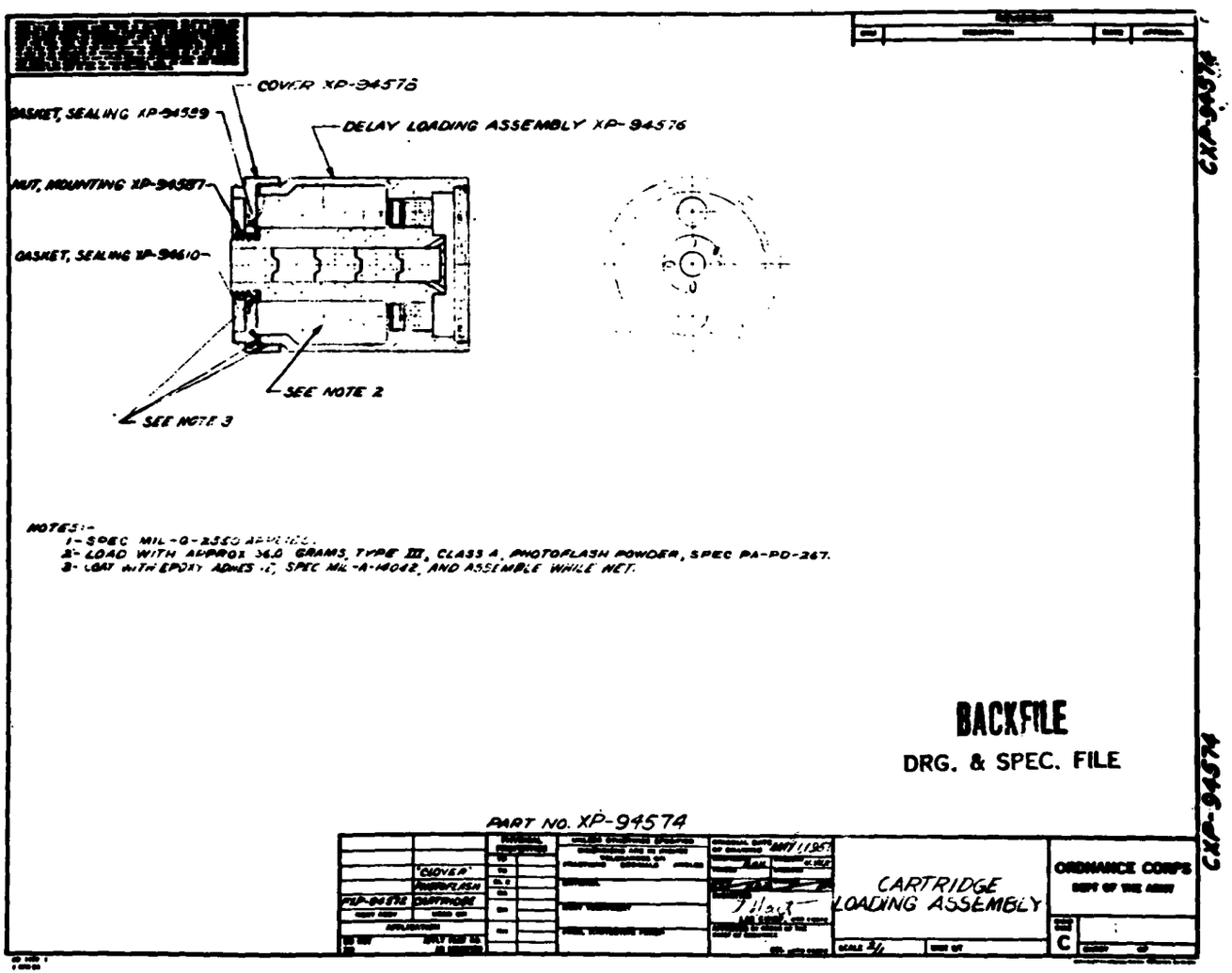

Fig 2 Loading assembly

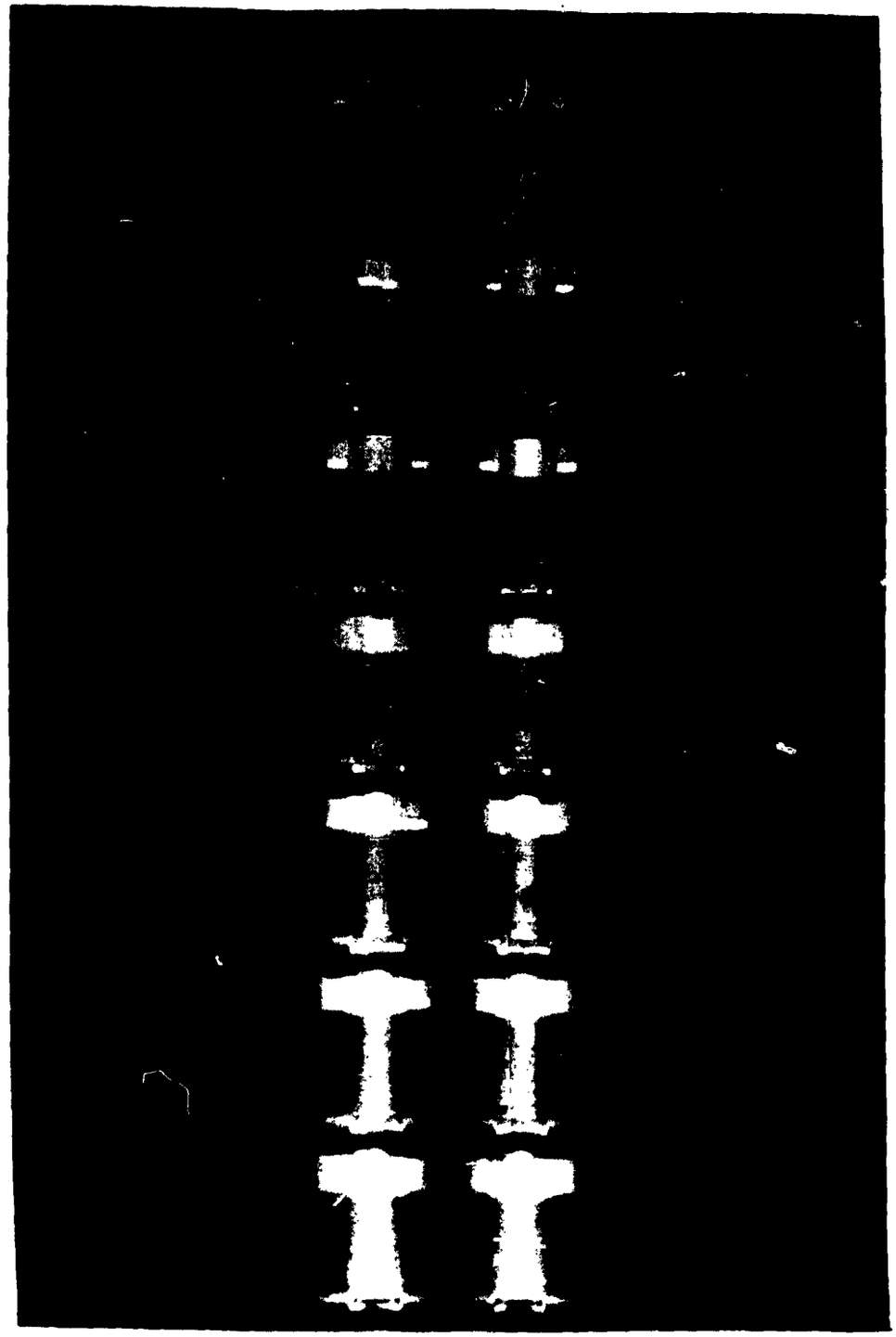

Fig 3 X-ray of typical Clover cartridge assemblies

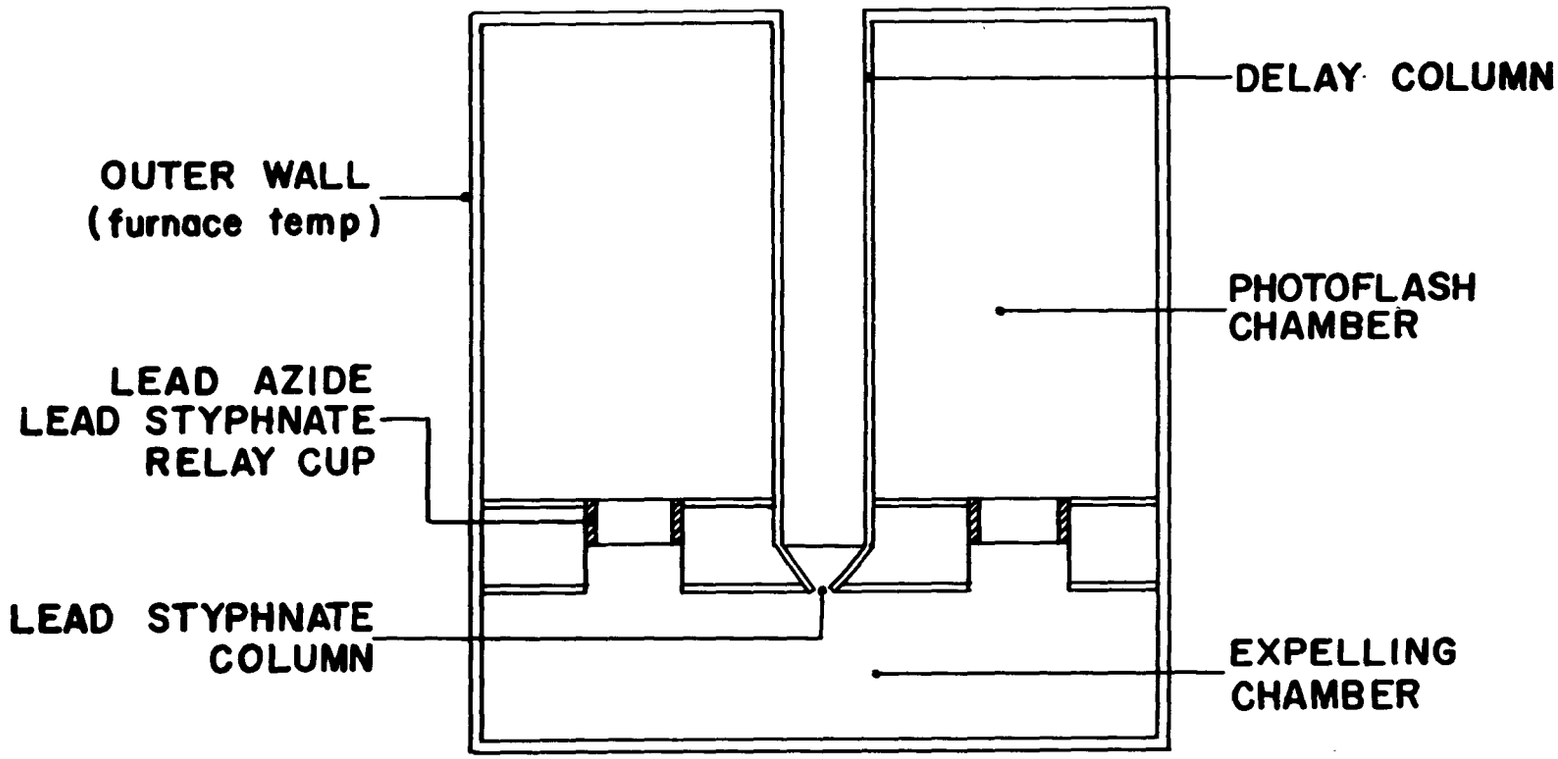

Fig 4 Position of thermocouples in the Clover cartridge (thermocouples were placed at all of the positions identified in this figure.)

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(over)

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1. Photoflash cartridges – Prematures
2. Calcium – Sensitivity

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II. Kaye, Seymour M.
III. CLOVER
IV. FP 790
V. Ord. Proj TS5-5407
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2. Calcium – Sensitivity

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X-ray examination of Clover cartridge assemblies showed no discontinuities in component packing, and 40-foot free fall tests did not cause detonation of Clover cartridges containing FP 790 only.

A possible explanation of the premature detonations obtained during series firings is given based upon omission of the black powder/barium chromate expelling charge.

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